An Energy Efficiency Workshop & Exposition

Kansas City, Missouri

Evaluating Power Quality Problems in Existing Facilities

Presented by: Dan Carnovale; P.E.

Cutler Hammer Engineering Services

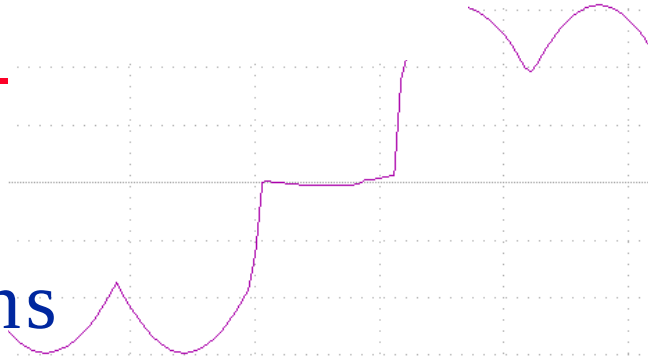
DanielJCarnovale@eaton.com

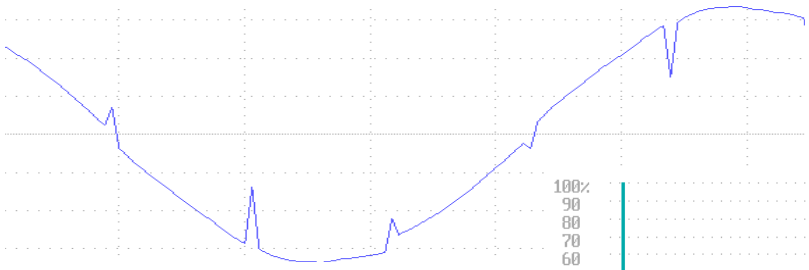
Power Quality Demonstration

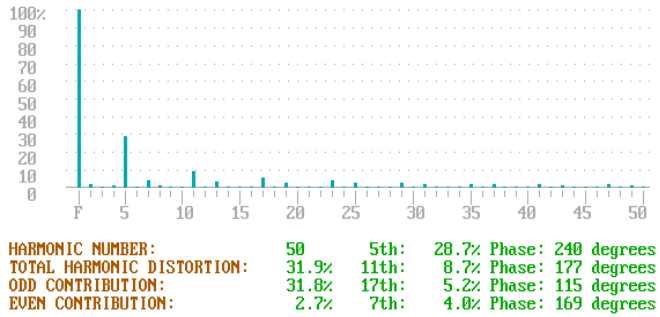
- What did you see???
- What did you hear???
- What was it???
- Think of your power system - How much would it cost you???
- How can you “fix” the problem???

Power Quality

- Power Quality Concepts
- Illustrate Power Quality Solutions using Case Studies
- Industry Trends







Power Quality Confusion

What is Power Quality?

- "The concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of that equipment."[1]
- "The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment (and compatible with the premise wiring system and other connected equipment)"[2]
- The definition of Power Quality cannot be limited to the characteristics of the supply power. The definition must also include the requirements of the load and neighboring loads.

[1] IEEE 1100-1992

[2] IEEE 1100-1999

IEEE Recommended Practice for Powering and Grounding Electronically Challenged Equipment

How does PQ Affect My Logic System?

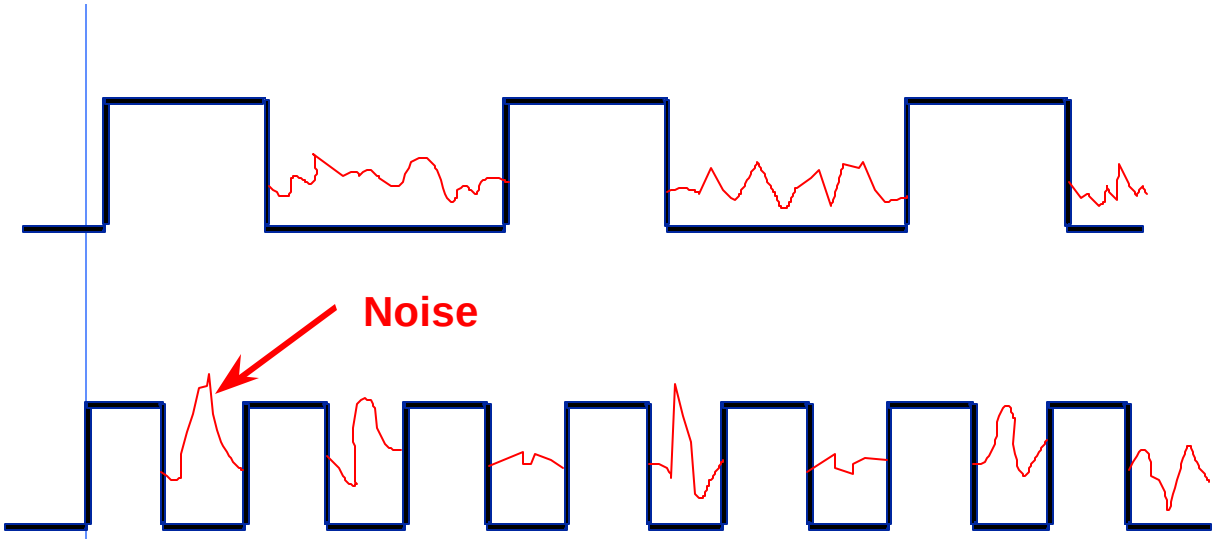
Power disturbances create physical damage and swamp logic signals in electronic equipment. Noise disturbances can be interpreted as legitimate ON / OFF signals, resulting in operating errors and equipment downtime.

A. Past Signal Voltage Levels

20 - 30V logic signal

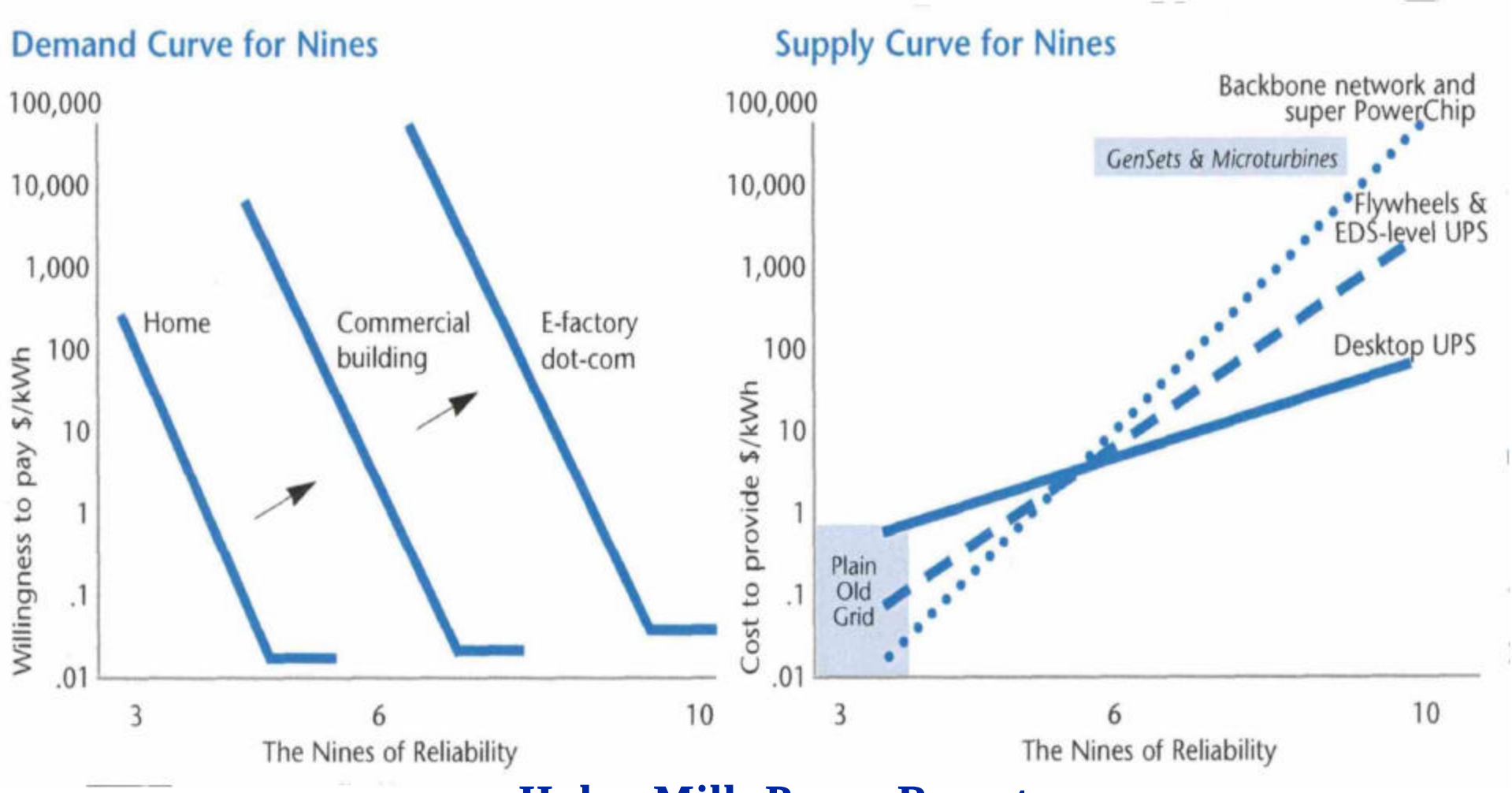
B. Modern Voltage Levels

3-5V logic signal



Source: EC&M, 1993

The Reliability Factor



Huber Mills Power Report

How Much Downtime is Acceptable?

Reliability	Avg Disruption / Year
99 %	88 hours
99.9 %	8.8 hours
99.99 %	0.88 hours
99.999%	5.3 minutes
99.9999%	32 seconds
99.99999%	3.2 seconds

- Each additional "9" increases reliability & facility uptime…. improving productivity

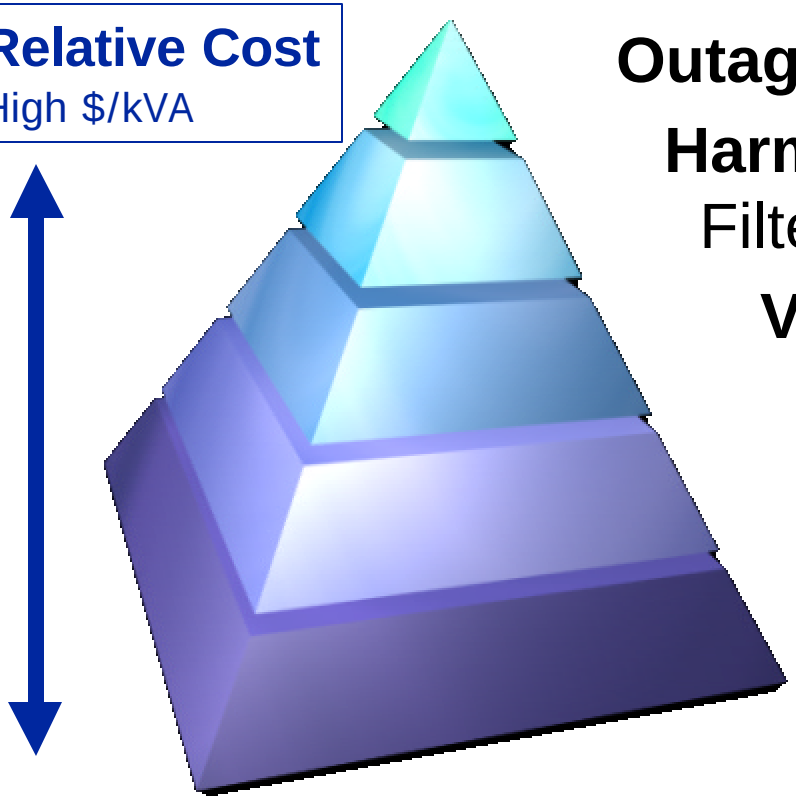
- the Power Quality solution depends upon the required uptime!

- Data centers = $$$$$ solution
- Industrial Process = $$$
- Retail Facility = $$
- Residential = $

99.99999999% - The trend for dot.coms/E factories

Power Quality Pyramid™

Relative Cost
High $/kVA



Low $/kVA

Outages (UPS; ATS; Flywheel)

Harmonic Distortion (Active& Passive Filters; K Factor transformers)

Voltage Variations (Tap Changer, Sag Correction, Ferro's, DVR)

Surge Protection (AC,DC,Dataline)

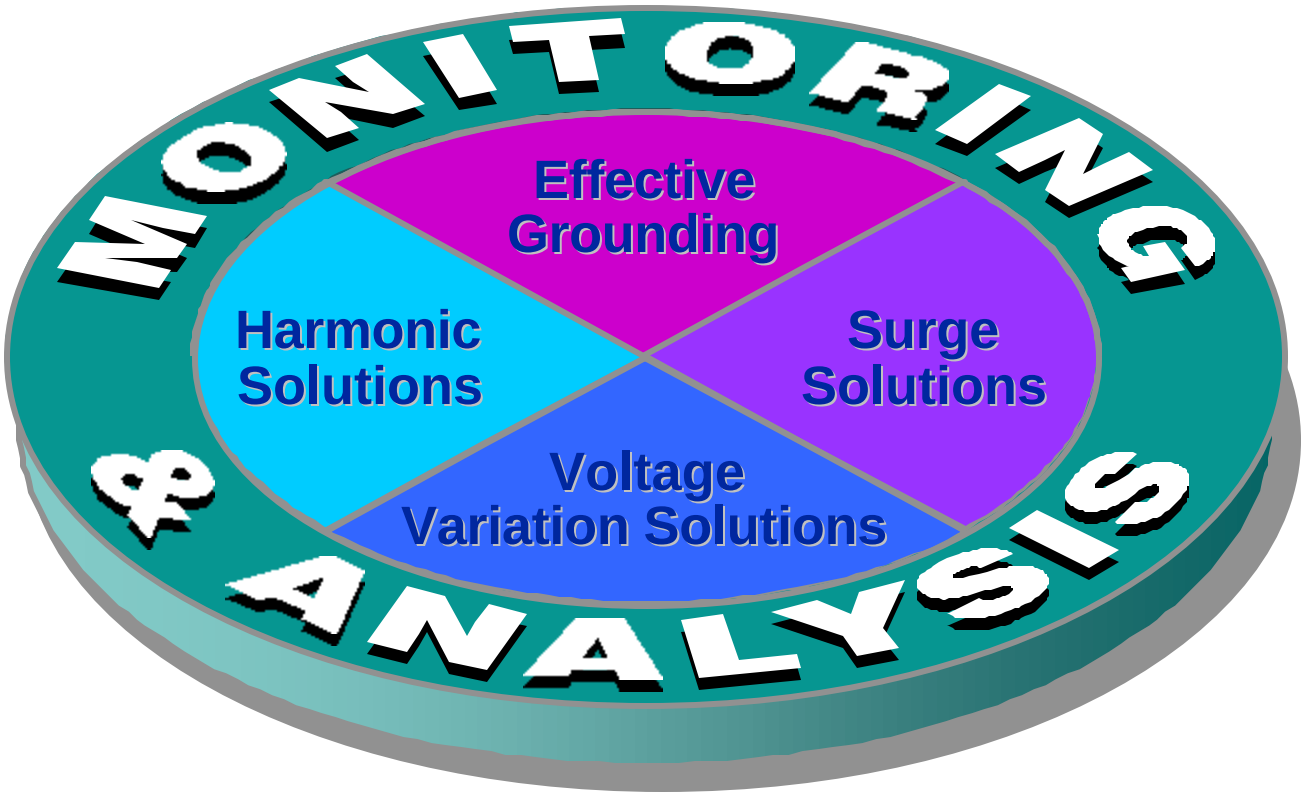
Grounding/Bonding (ground rods fittings, lightning system)

The P.Q. Pyramid: Start with Grounding; add other mitigating products where required

Power Quality Application Considerations

- Ensure ground system integrity
- Limit creation of power quality problems caused by loads
- Attenuate power quality problems caused by external sources
- Withstand poor power quality (according to economic considerations)

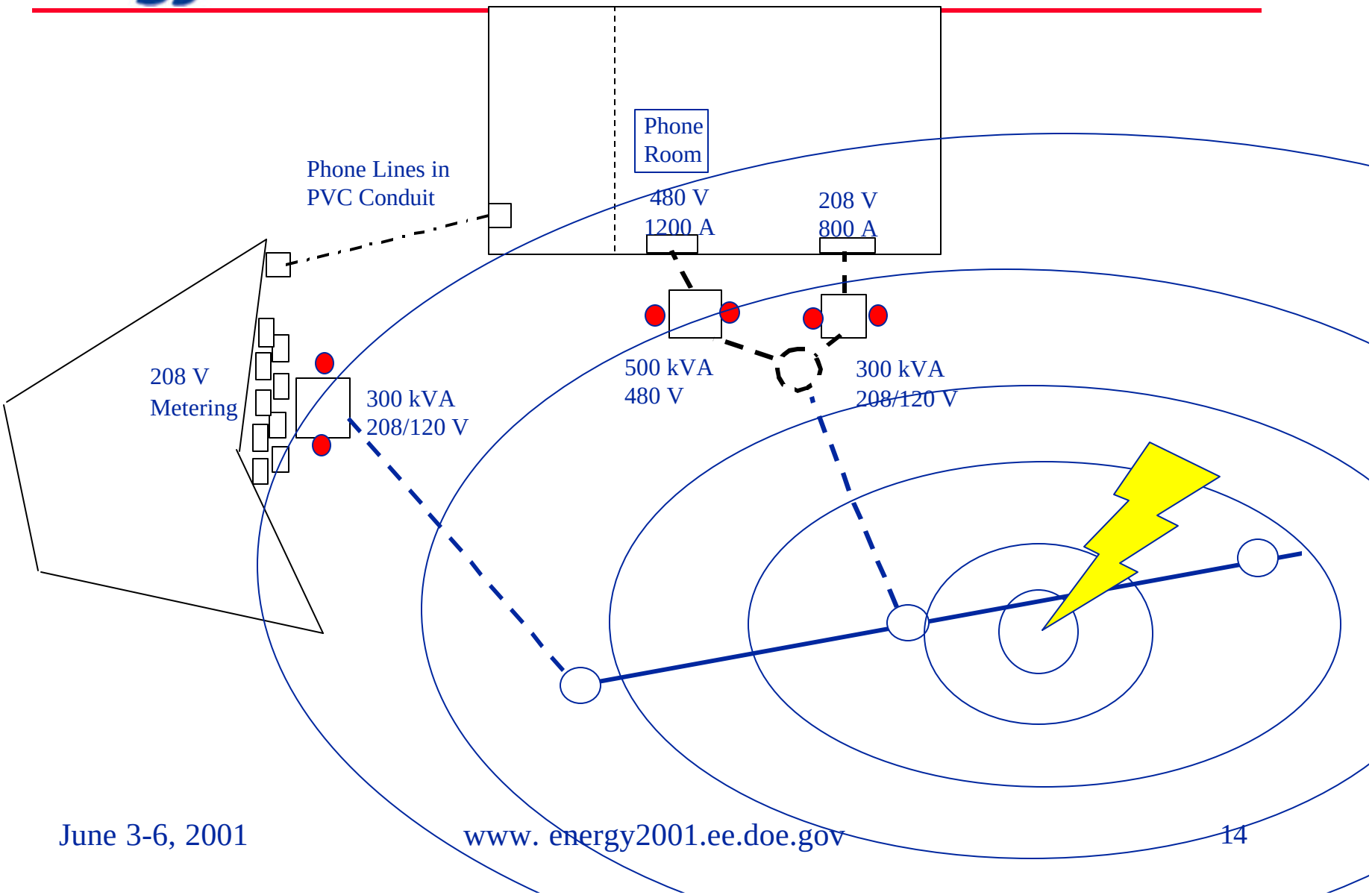
Power Quality Concepts



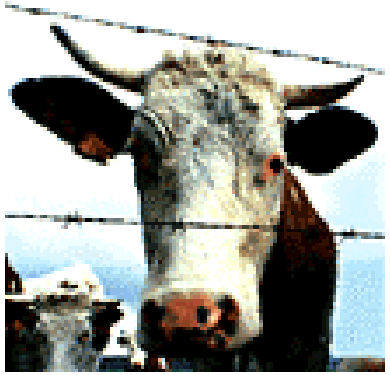
Grounding

- .....Because you should never underestimate the importance of a good foundation!

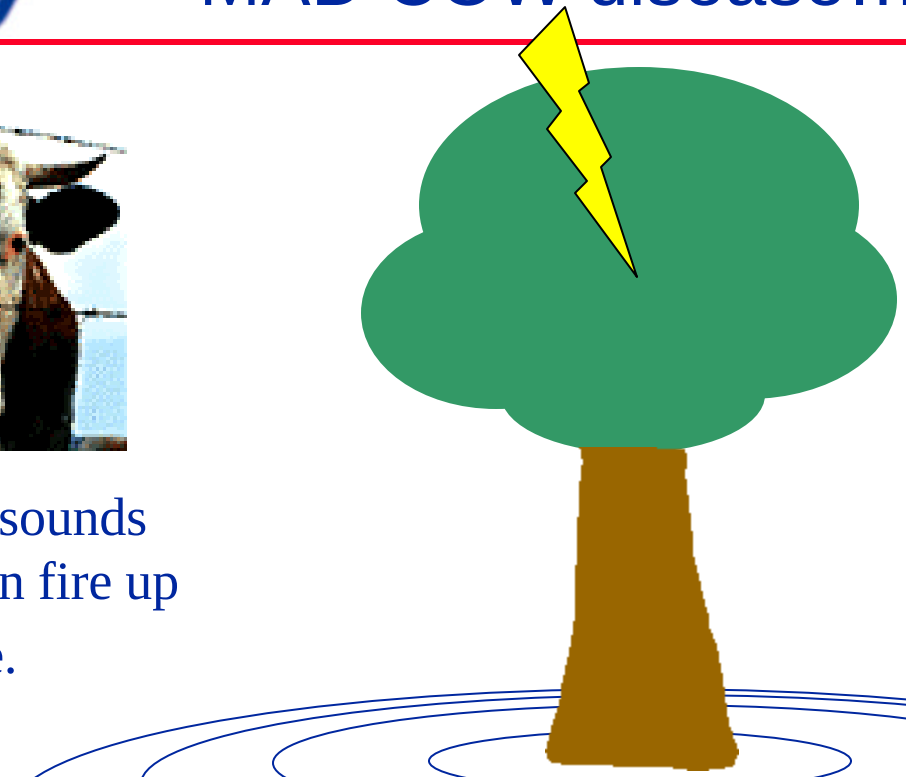
Grounding Example



How to identify if your cow has MAD COW disease……



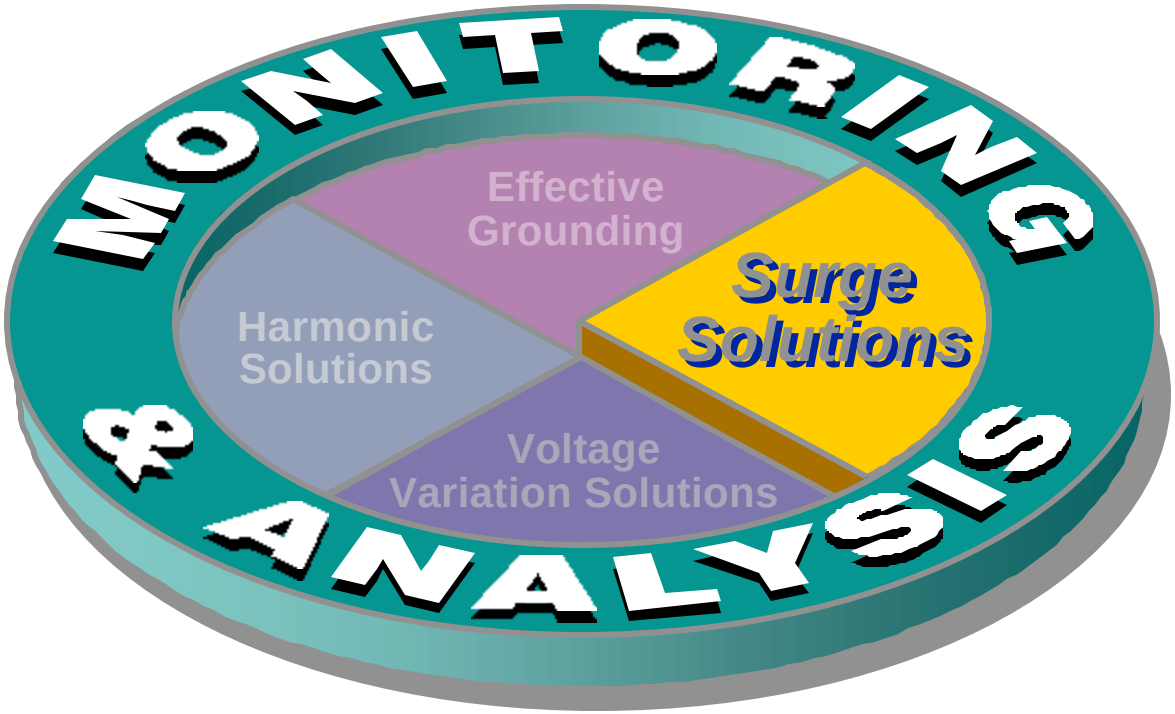
If your cow sounds like this, then fire up the barbecue.



If your cow sounds like this, then may we suggest the fish.

Surge Protection

- The two sources of surges / transient overvoltages that account for the majority of all events are switching and lightning



Sources of Surge Voltages

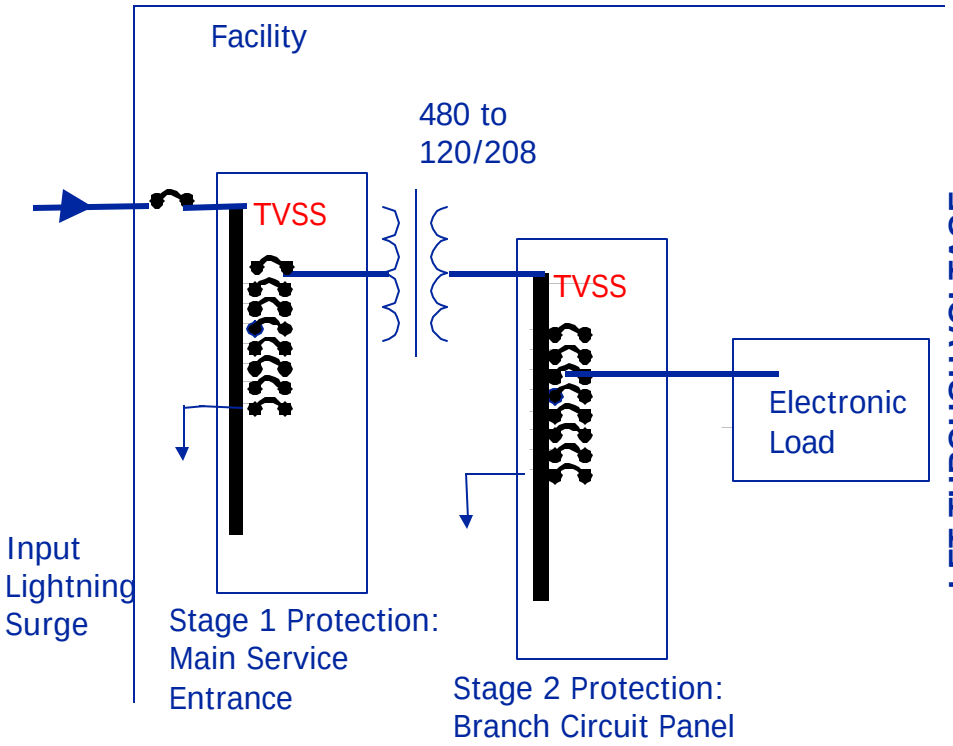
Common External Sources

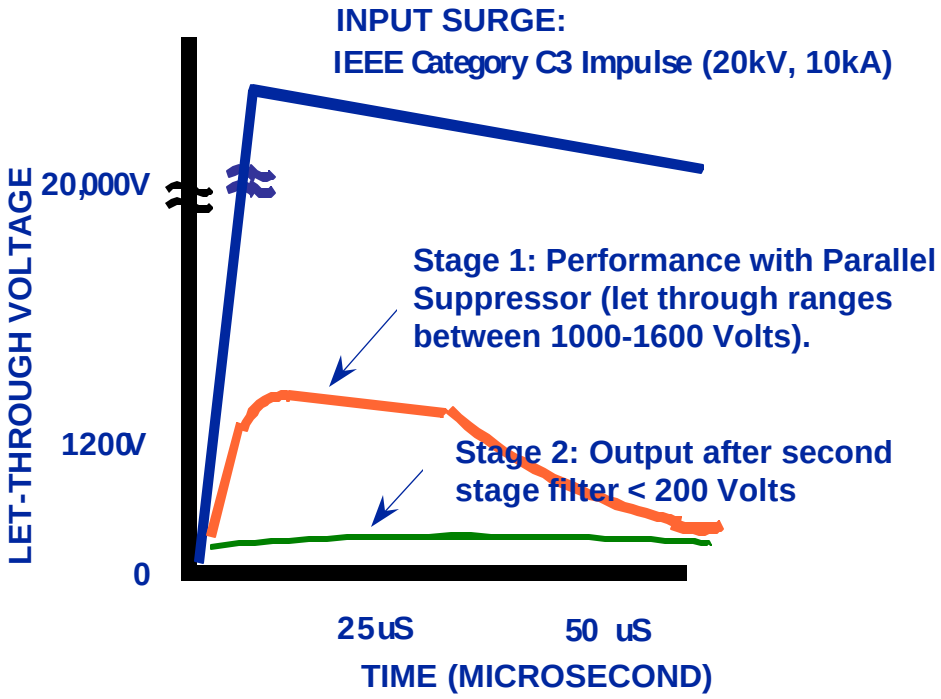
- Lightning
- Capacitor switching
- Short circuits

Common Internal Sources

- Load switching
- Short circuits
- Capacitor switching
- Imaging equipment operation
- Variable speed drive operation
- Arc welders
- Light dimmers

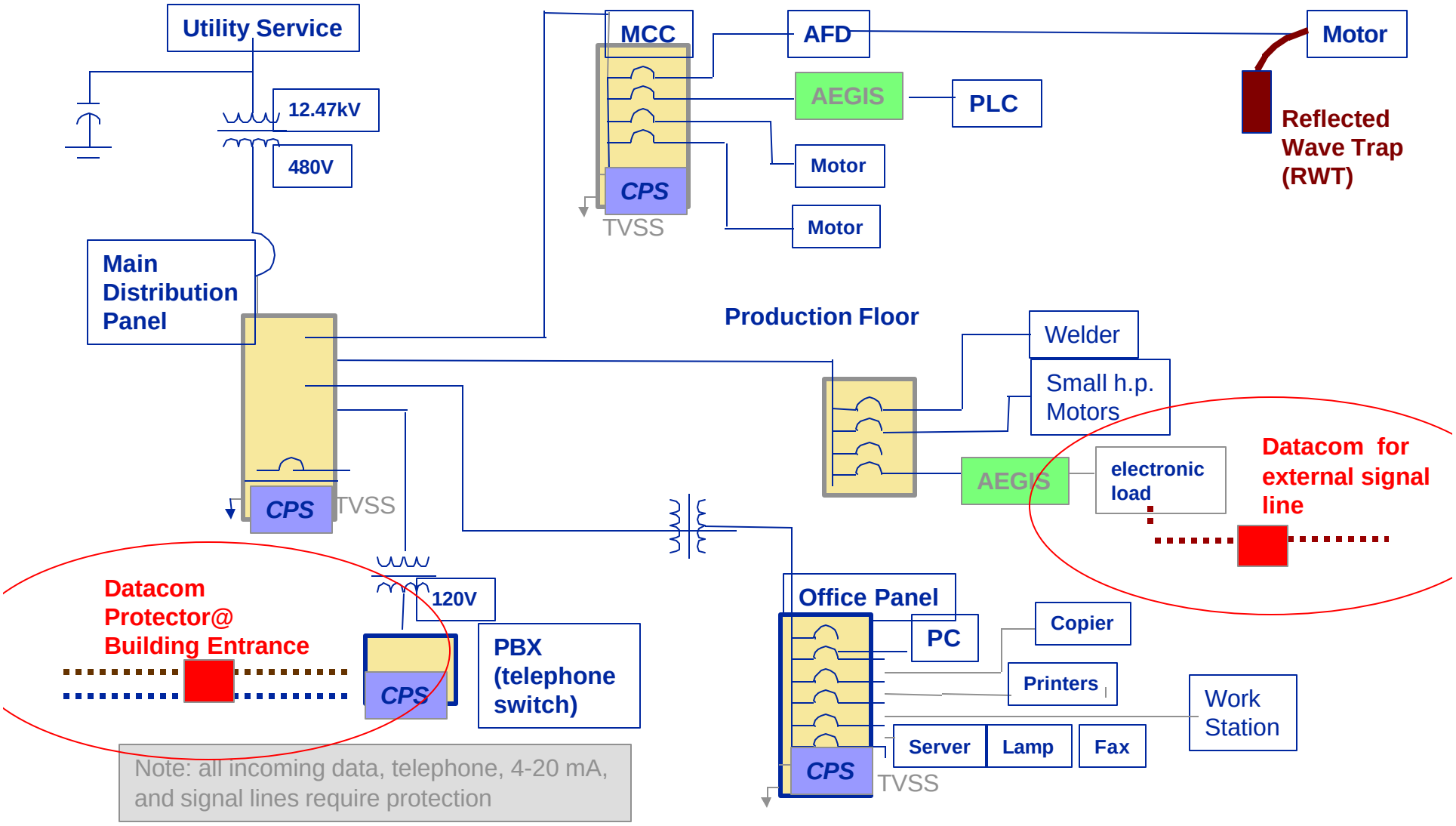
"Two Stage" Protection Plan





System Test Parameters:
Input Wave: IEEE C62.41 Category C3 Surge (20 kV; 10 kA)
Test procedure: IEEE C62.45
System Voltage 230 Volt (Phase-Neutral)

Surge Protection... Don't Forget the Backdoor



How to Specify A Quality Suppressor

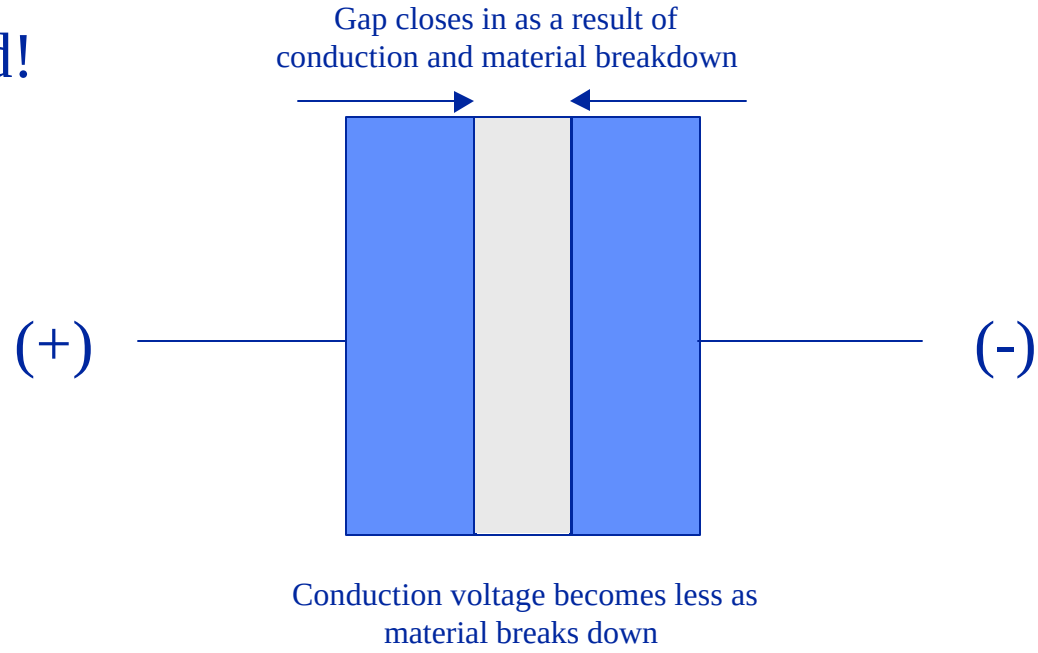
- Surge Current Per Phase (appropriate sizing for long term protection)
  - Spec: 250 kA / Phase (service), 120 kA / Phase (branch locations)
- Integrated Installation (lowest possible let through voltage)
  - Spec: Surge supplied by electrical distribution manufacture
  - Spec: Surge mounted via direct bus bar connection
- Low "Let Through Voltage" (key performance measurement)
  - Spec: UL 1449 rating of 400V (208V system), 800V (480V system)
  - Spec: Cascaded (2) level system design a per IEEE Emerald Book
- Quality Construction (ability to achieve published performance)
  - Spec: all suppression components mounted directly to a solid copper surge plane
  - 3rd part independent test results to verify quoted surge current ratings

MOV Failure

TVSS's with MOV's become better with time (following multiple operations)…. until they fail!

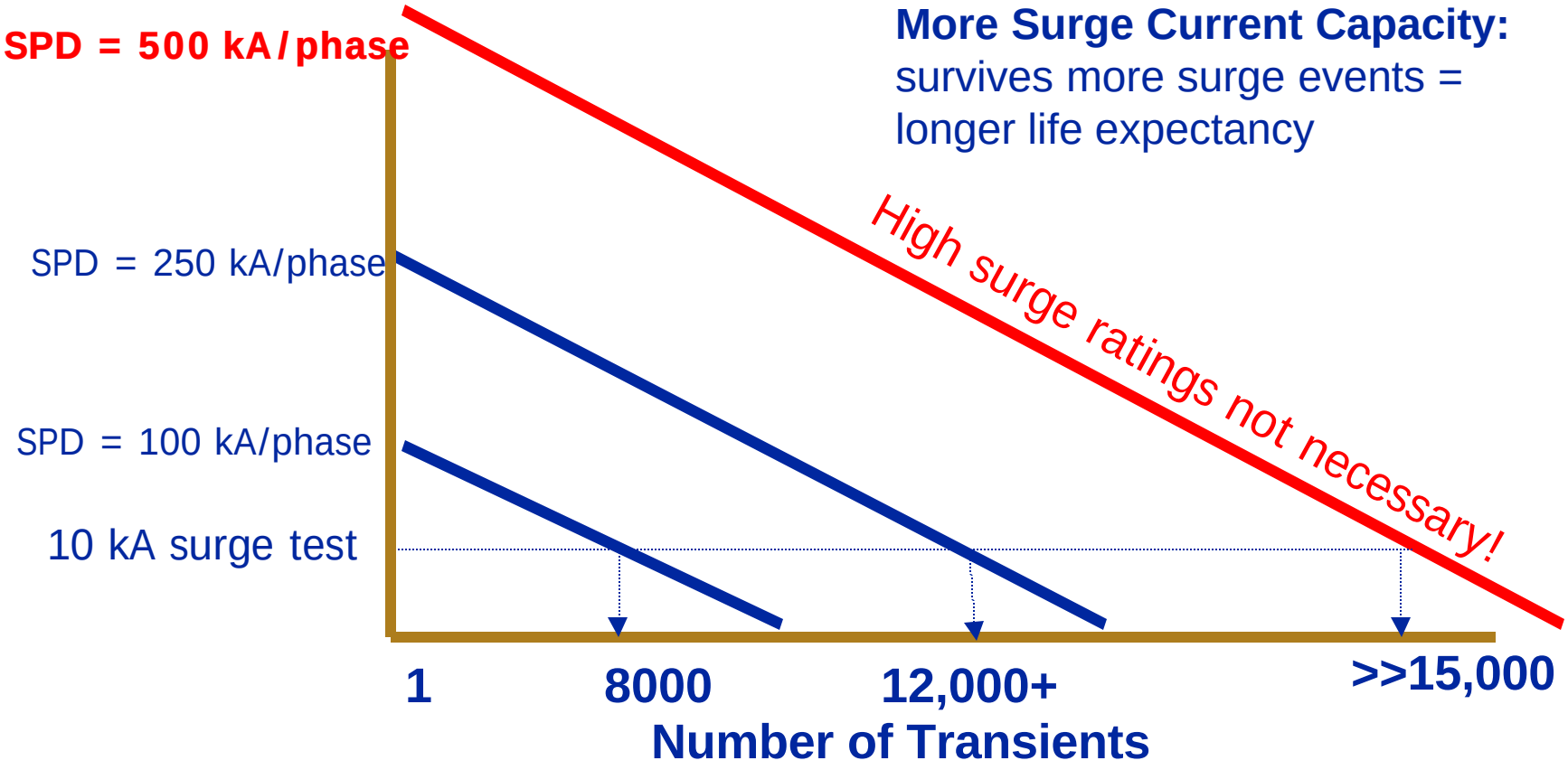
MOV's Fail Shorted!

Here's how…



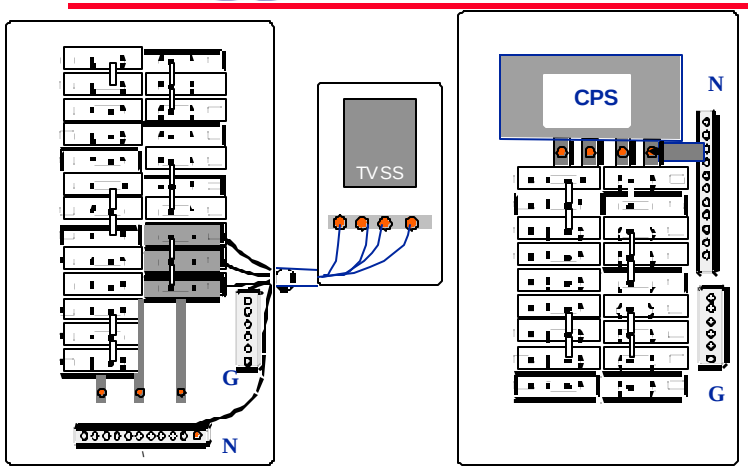
Overvoltage (RMS) is the #1 Killer of TVSS's!!!

Surge Current Ratings: Higher Capacity = Increased SPD Life



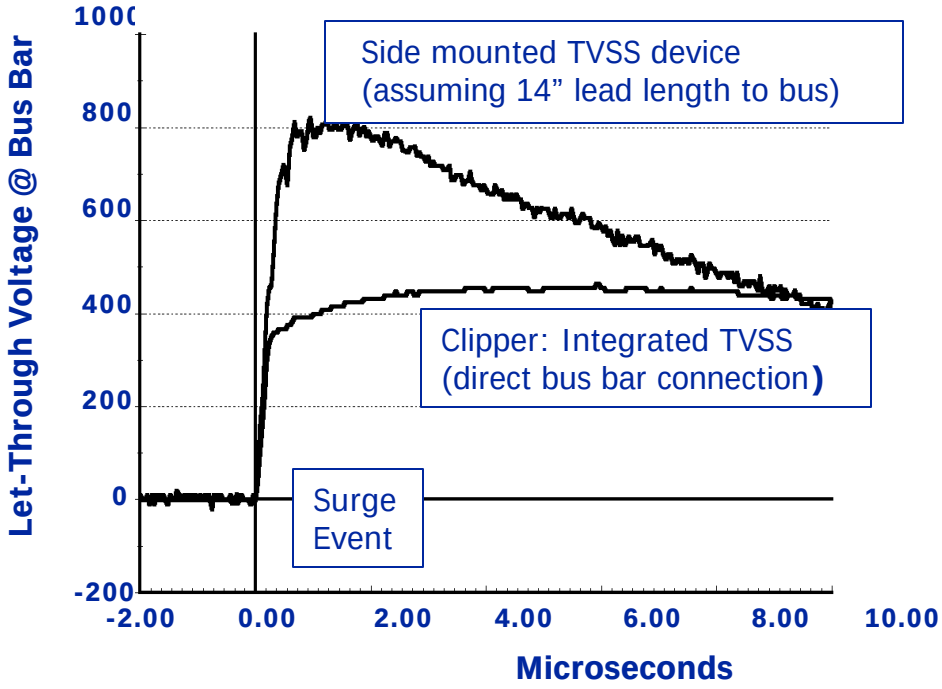
- 250 kA/phase is enough for any facility (>> 25 year life in Florida)
- Manufacturer's promote high ratings (500 kA) to sell for higher $$. The life expectancy for these units is over **200 years** !!!!

Integrated Surge is Preferred by Engineers



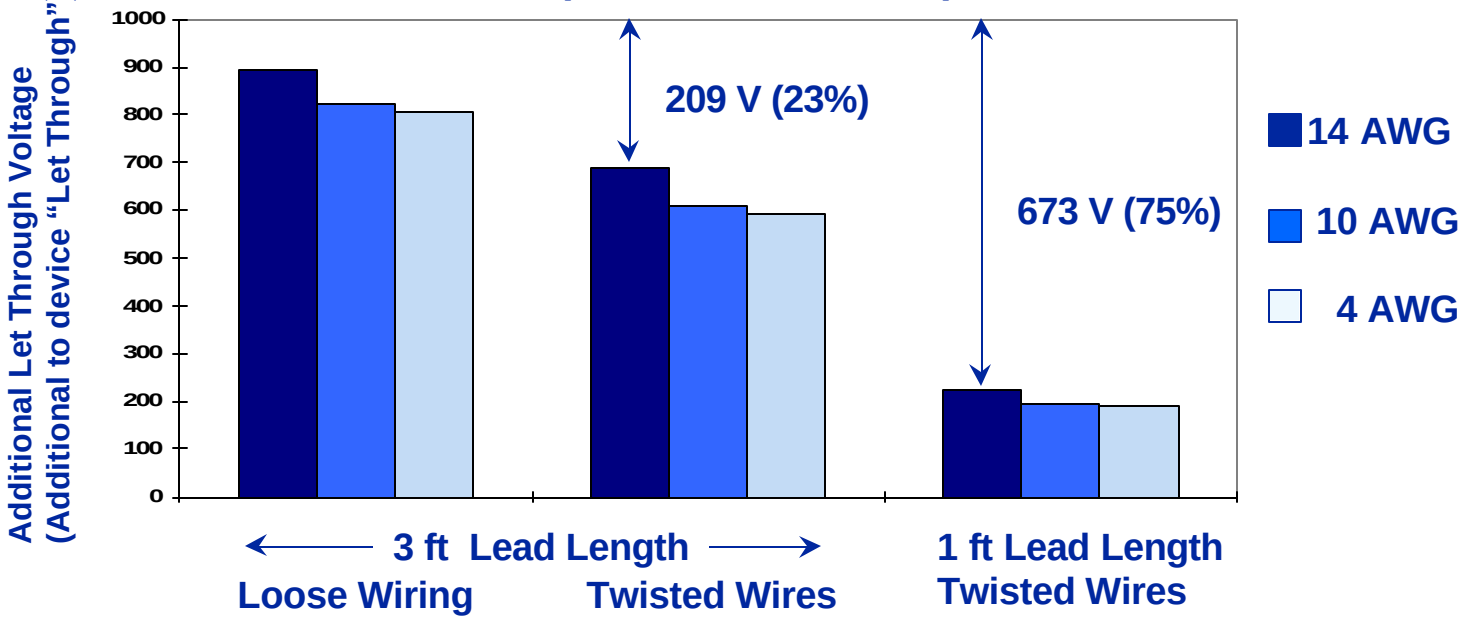
- **Less lead length = lower let - through voltage - 15-25 V/inch**
- **Eliminates installation costs**
- **Less wall space**
- **Higher performance**
- **Factory installed and quality tested**

208Y/120 Panelboard
(integrated versus side mounted TVSS)



Installation Lead Length Can Increase Let-Through Voltage by 15- 25V per inch

Additional Let-Through Voltage Using IEEE C1 (6000V, 3000A) Waveform (UL1449 Test Wave)



Installation Criteria Order of Importance:

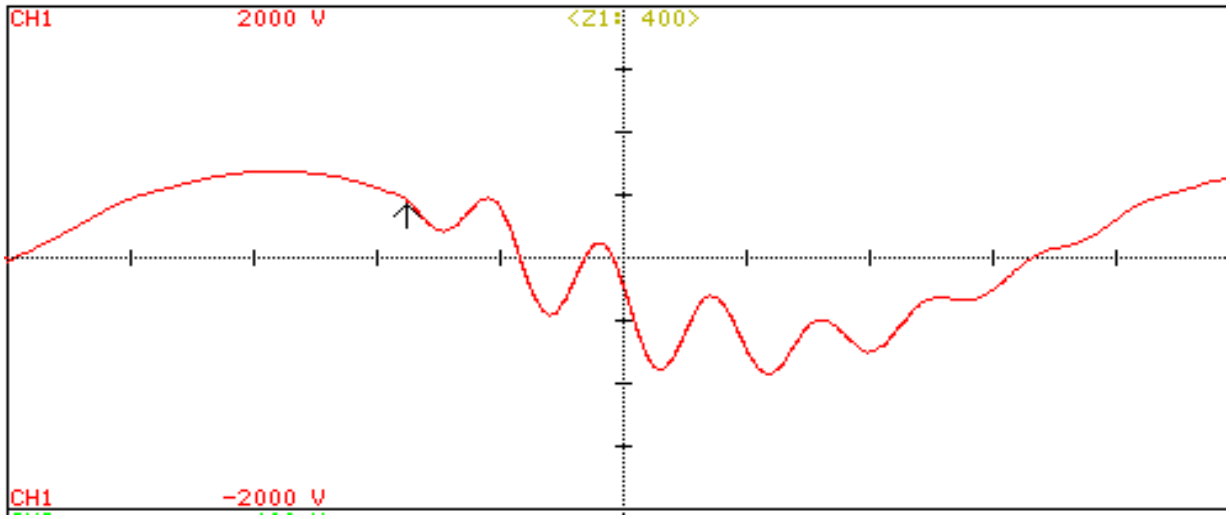
1) Lead Length - 75% reduction

2) Twisting Wires - 23% reduction

3) Larger Wire - minimal reduction

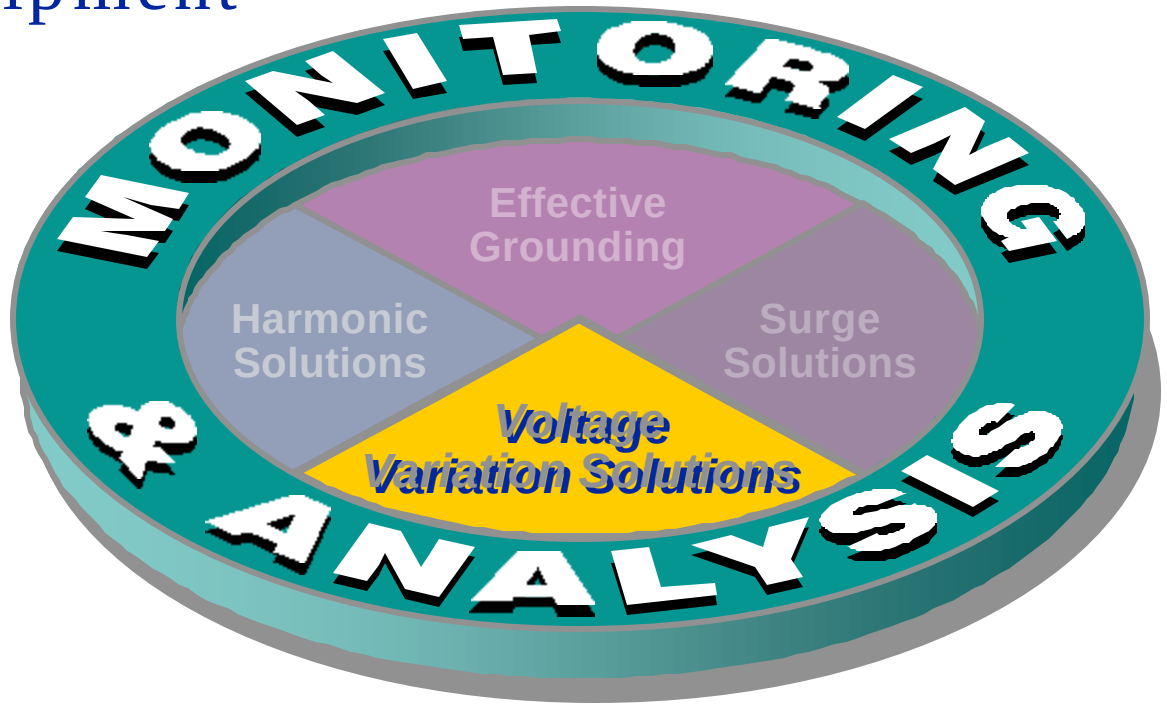
Transients - Capacitor Switching

- Problems with UPS Alarms
- Problems with Multiple Zero Crossings



Multi-Cycle Voltage Variations

- Sags are responsible for a majority of upsets and nuisance trips of sensitive electrical equipment



Symptoms of Voltage Sags

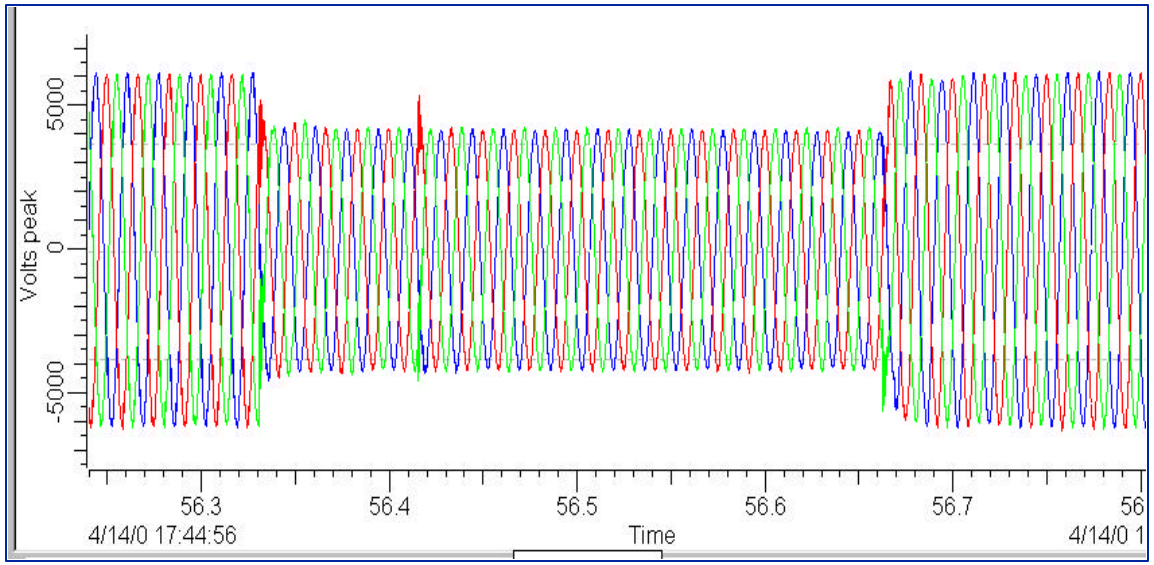
- Computer Rebooting or Locking-Up
- Contactors Chatter or Open
- PLCs Locking-Up and Process Stoppage
- Corrupted data
- HID Lamps Shutting Off
- Incandescent Lamps Flickering

Sources of Voltage Variations

- Supply Side Variations (Faults on Power System)
- Local Faults
- Power Factor Correction Capacitors
- Load Switching
- Regulator Malfunction
- Load Side Variations
- Motor Starting

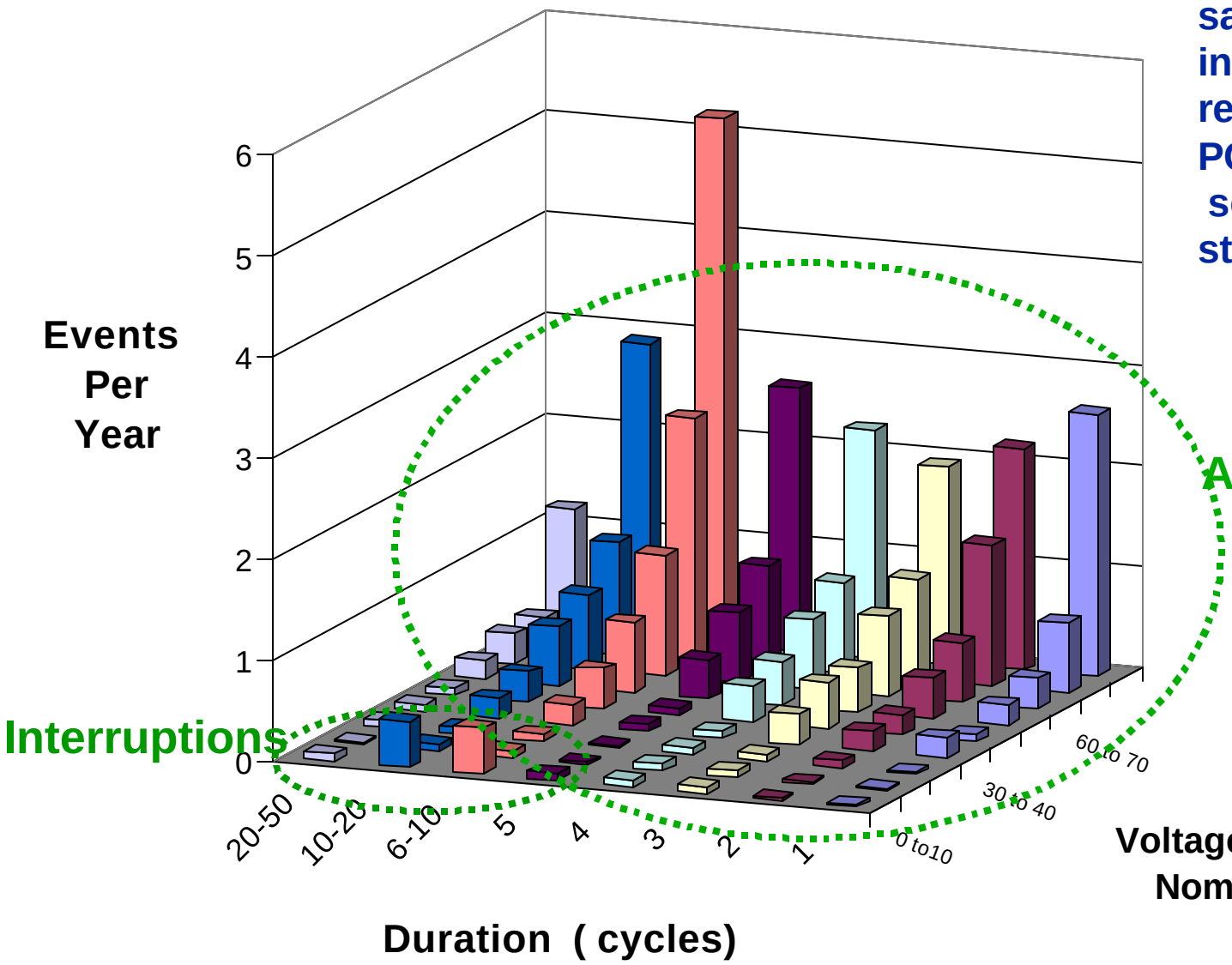
Voltage Sag Characteristics

- Retained Voltage
- Duration
- Number of Phases Affected



Sags are the Most Costly P.Q. Problem

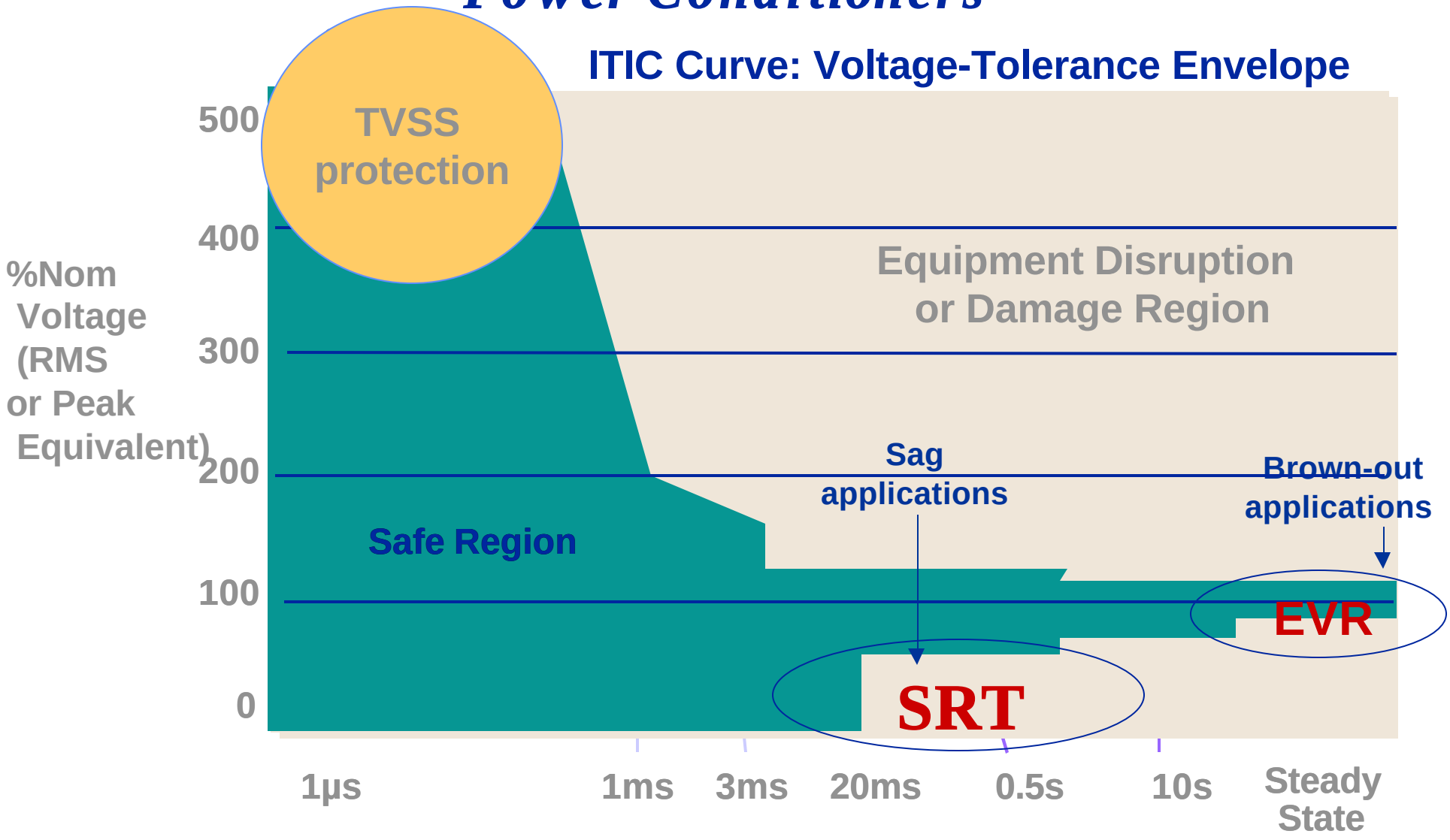
(92% events are sags; 4% short term interruptions remainder are other PQ problems)
source:EPRI, DPQ study of 300 sites)



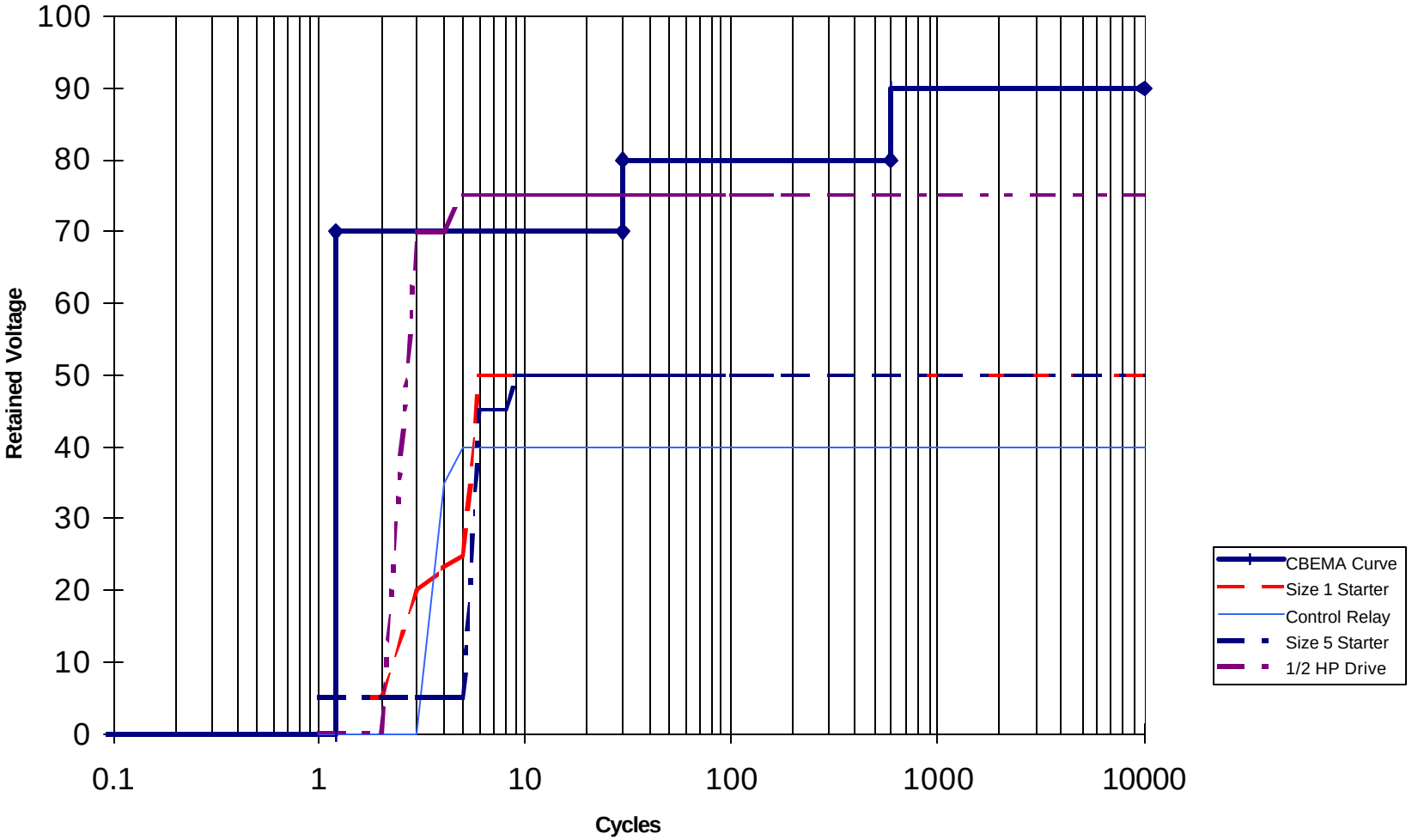
Average = 50 Sags/Year

Interruptions

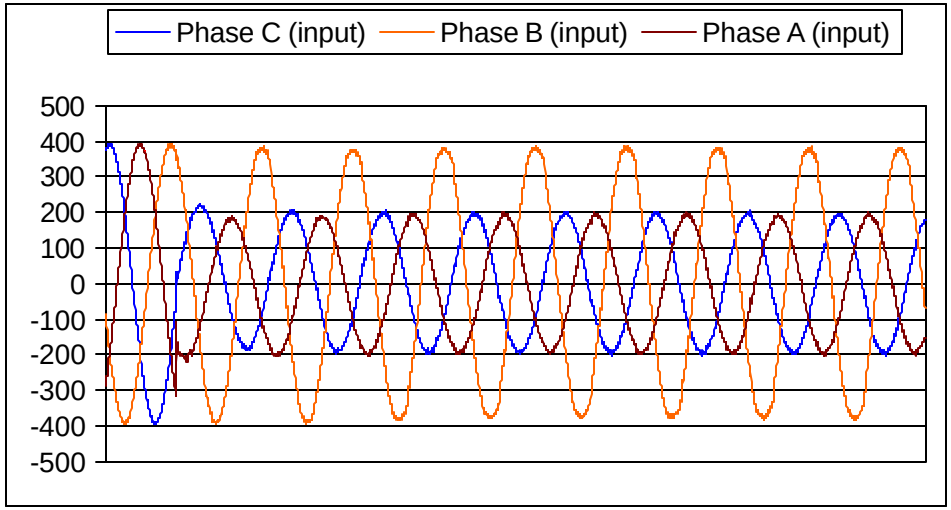
Where to Apply C-H SRT or EVR Power Conditioners



CBEMA Curve Testing

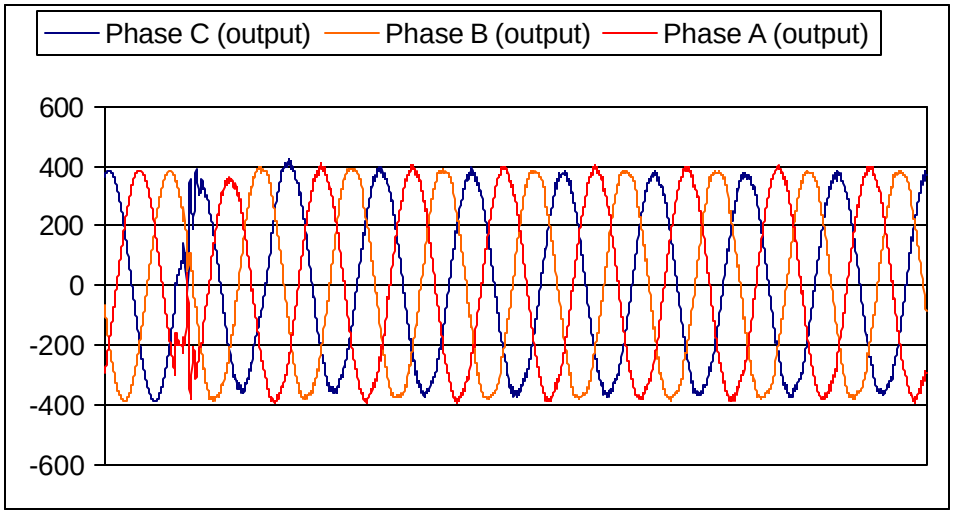


SRT Sag Corrector



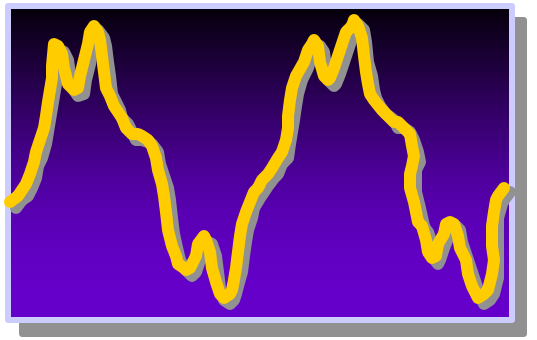
Before

After



Harmonic Distortion

- Harmonic problems are becoming more apparent because more equipment that produce harmonics are being applied to power systems



Symptoms of Harmonics

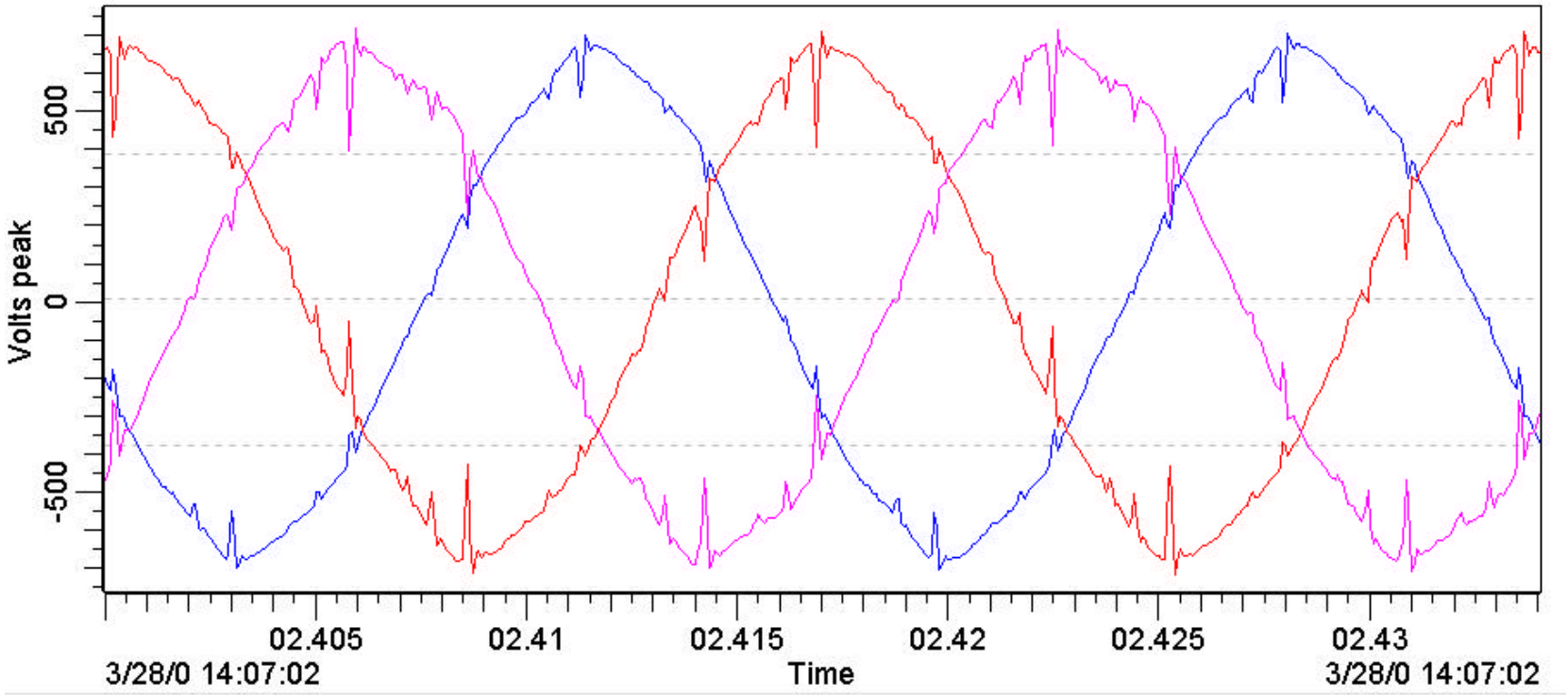
- Transformer heating
- Motor and generator heating and vibrations
- Neutral heating
- Nuisance fuse operations
- Insulation deterioration
- Electronic control malfunctioning
- Inconsistent meter readings
- Voltage regulator misoperations

Sources of Harmonics

General categories of common types of nonlinear loads are:

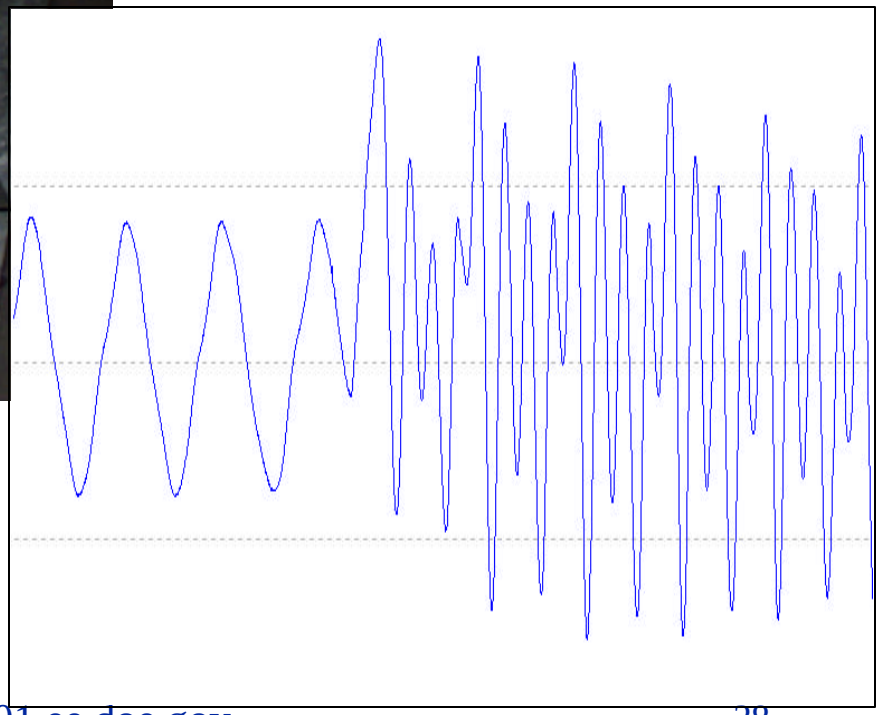
- Power electronic equipment
- Arcing devices
- Iron saturating devices
- Rotating machines

Voltage Notching



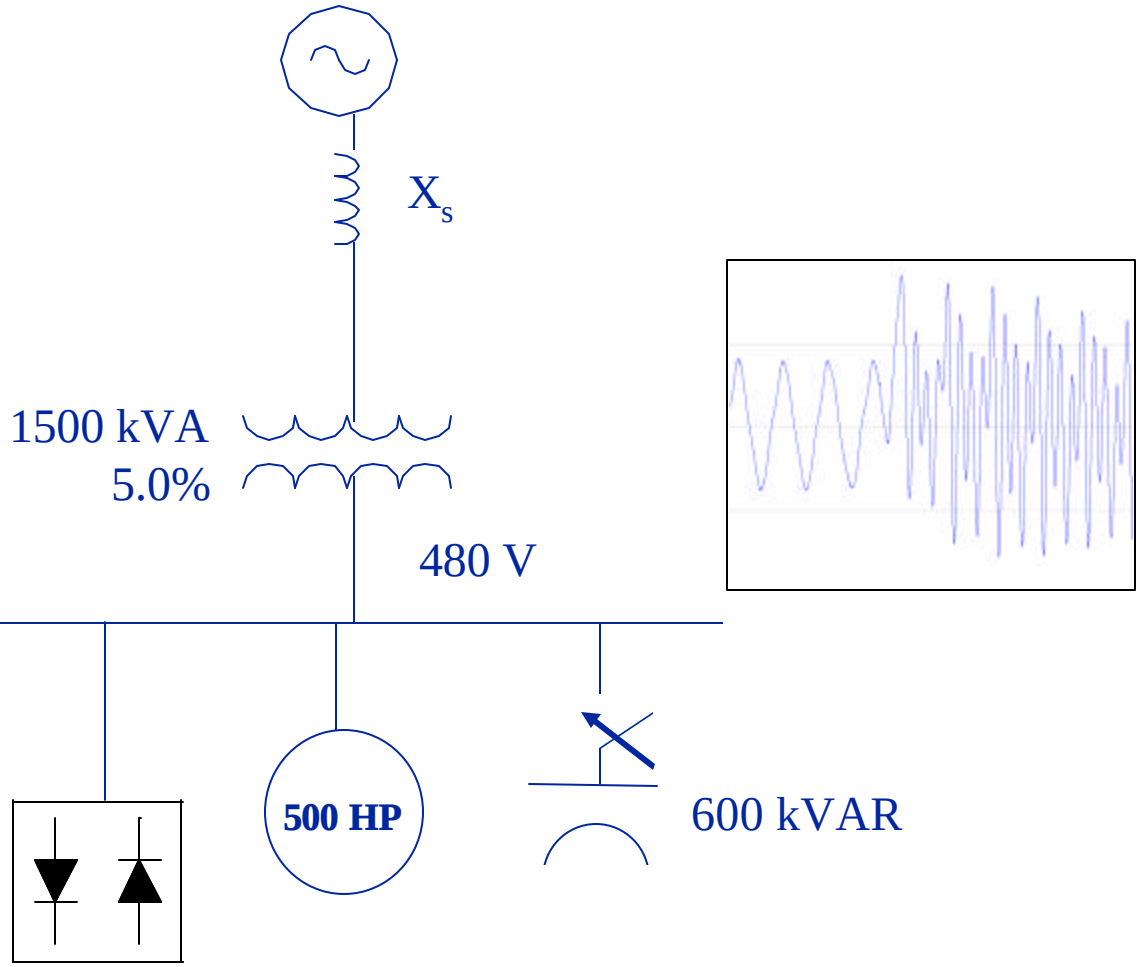
Measurement	Minimum	Maximum
Time	March 28, 2000 14:07:02.399	March 28, 2000 14:07:02.434
Voltage Waveform L1L2 Inst.	-702.2Vpk	707.1Vpk
Voltage Waveform L2L3 Inst.	-715.8Vpk	711.9Vpk
Voltage Waveform L3L1 Inst.	-703.6Vpk	719.8Vpk

Parallel Resonance



Parallel Resonance

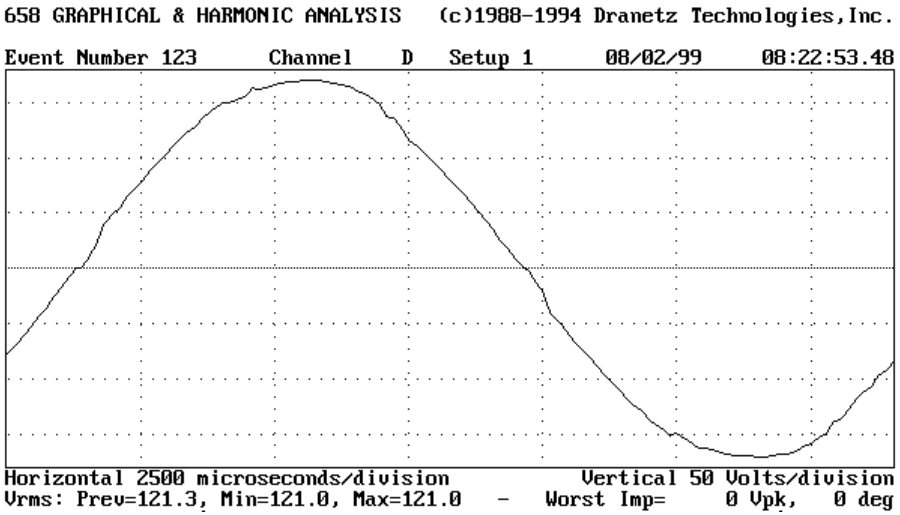
$$f_R = \sqrt{\frac{MVA_{SC}}{MVAR_{CAP}}}$$



Corrective Actions

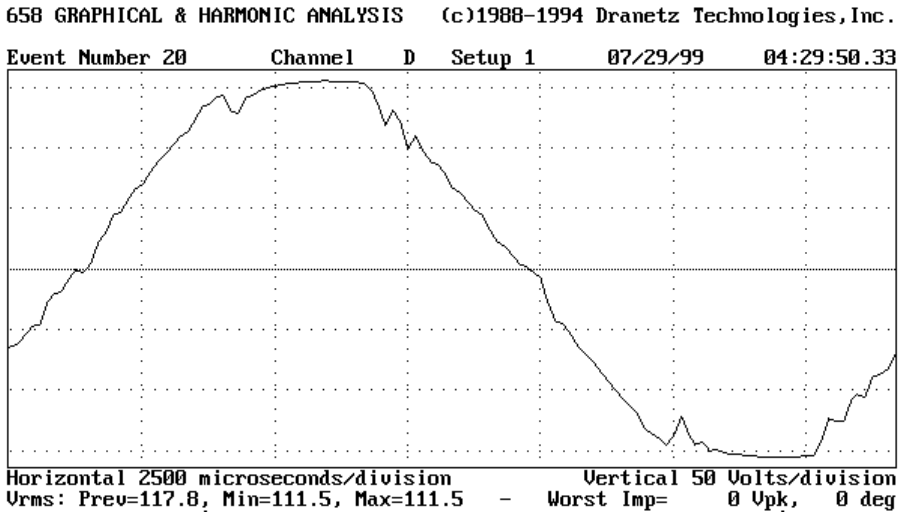
- Passive harmonic filters
- Active harmonic filters
- Zero-sequence traps
- Harmonic cancellation
- Isolation transformers
- Commutation reactors
- 200% neutral conductors
- K-factor rated transformers

Harmonics and Generators



Utility Source
2.3% THD

Generator Source
5.7% THD
Same Load



Monitoring Solutions

"If you don
you can't manage it."

"… but, don't be data rich
and solution poor!!!"

Power Quality Monitoring

- Permanent Monitor vs. Portable
- Monitor main bus with a full-function power quality monitor - Program it!!!
- Take advantage of embedded monitoring technology when available
- Pinpoint the source of disturbance

Permanent Monitors

- Monitor voltage sags
- Monitor load data and harmonics necessary for the performance of a power factor / harmonics study
- Monitor energy for cost allocation and efficiency - energy usage is the ONLY unchecked invoice that we pay without verification

Other PQ Considerations

Magnetic Field Effects

- Computer Screen "Jiggling"
- 20 mG or Higher
- Relocate Monitor - Field Reduced by Square of Distance

Peak Sensing Equipment - Trips on Harmonic Current

- Apply RMS Sensing or Reduce Peak Current

Neutral Overheating or Burning

- Double the Neutral or Single Full Size Neutral Per Phase
- Zig-Zag Transformer to Reduce Triplen Harmonics
- K-Factor (to Live With Harmonics)

Methods to Calculate P.Q. Costs

1. Cost: $ per event

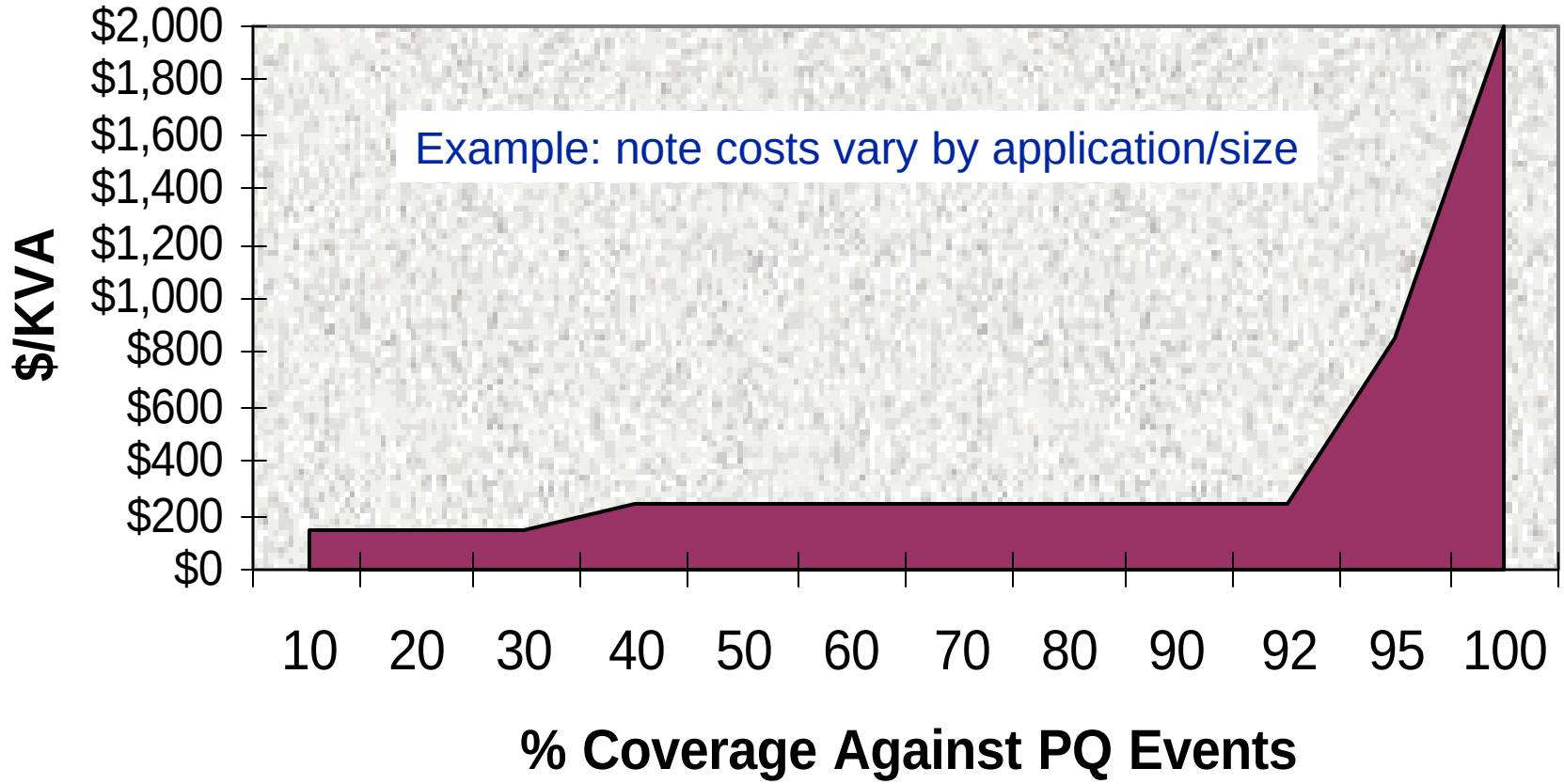
- **$1000's to $100,000 per event** ($10,000 for many companies)
- **depends on process** (scrap costs, lost revenue, start-up costs)
- **help customers analyze financial their costs**
- **Necessary to justify improvement projects**

2. Cost: $ per KVA/year

- **$50 -$250 per KVA of sensitive load (what a business owner loses when equipment goes down)**
- **U.S. Average = 15% of Total Load is Sensitive** (>50% for Plastics Injection; >80% for telecommunications)
  - **Example** (ABC plastics company - 600 kVA total facility load):
  - Estimate sensitive loads @ $50% = 600 x 0.5 =300 kVA
  - Estimated down time cost = $15,000 to $75,000 per year (depending on facility, processes, customer impact)
- **Validate with your customer and recommend a way to save this money**

P.Q. Cost Curve: $/KVA for Percent Coverage

Cost to achieve 92% coverage is low - SRT solution
Cost to achieve 96% coverage is high - UPS
Cost to achieve 100% coverage is very, very high



P.Q. Solution Variations

Manufacturing Facility (Medium Sized 480 V, 1000A)

(eg. Plastics, Automation, or Higher Tech Assembly)

Possible P.Q. Solution	Capital ($ 000's)		
	Simple Solution	Med	Complex Solution
P.Q. Survey =	$0	$2	$15
Grounding equipment =	$0	$1	$5
Lightning System =	$0	$0	$20
Surge Protection (hardwire, datacom) =	$0	$5	$20
Surge Strips =	$1	$1	$2
Voltage Regulation/Sag Correction =	$0	$0	$60
UPS (servers, telcom system, other small boxes) =	$4	$8	$12
Harmonics (reactors, capacitors,)=	$0	$1	$20
Ferroresonant or other power conditioners =	$2	$4	$6
Power Quality Monitor =	$0	$1	$10
Total	$6.8	$21.4	$170.0

Does not include installation or ongoing maintenance

Other potential equipment: PDU, shielded isolation transformers, parallel gear, generators, ATS

PQ Value Chain

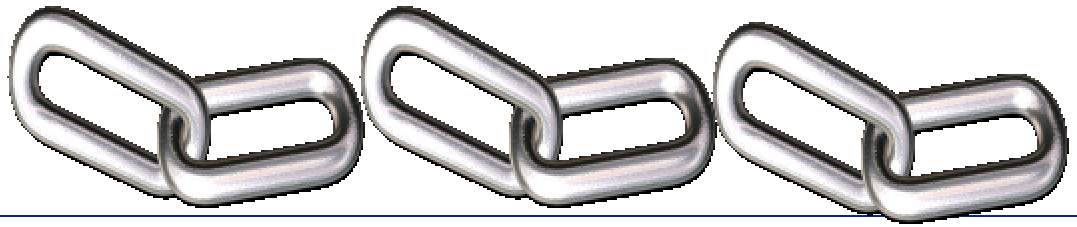
This is the recommend approach to solve a PQ problem. Good data and interpretation (advice), is key to a reliable solution

Customer: Problem or Potential PQ Requirement

Monitor → **Site Survey** → **Analysis & Recommendation** → **Products** → **Install Services** → **Maint'ce**

Customer: High Uptime & Reliability

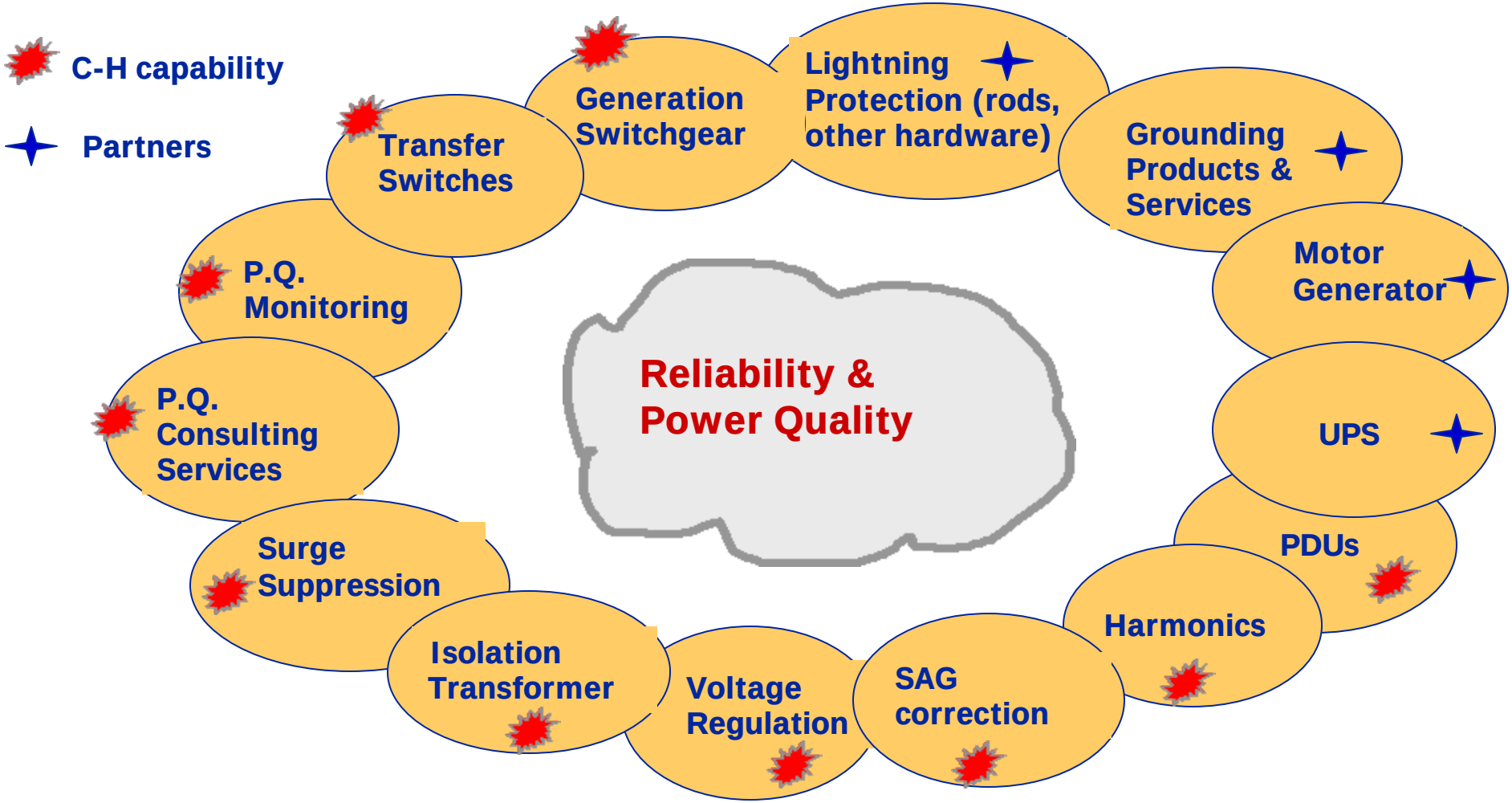
Critical competency for an effective PQ facility plan



Notes:

- Value Chain applies for new designs and retrofit/problem solving applications (some steps are modified)

Products & Services in this Market



Power Quality at C-H

New PQ Products and Services

- **The Performance Power Group - Integrated Approach - Products/Services**
- **Telephone - (800) 809-2772 Option 1, Sub-Option 2**
- **Email PQ Support - PQHotline@eaton.com**
- **Sag Correction & Voltage Regulation**
- **“Clean” MCC’s**
- **Web Access to Power Quality and Energy Management Monitoring Data**